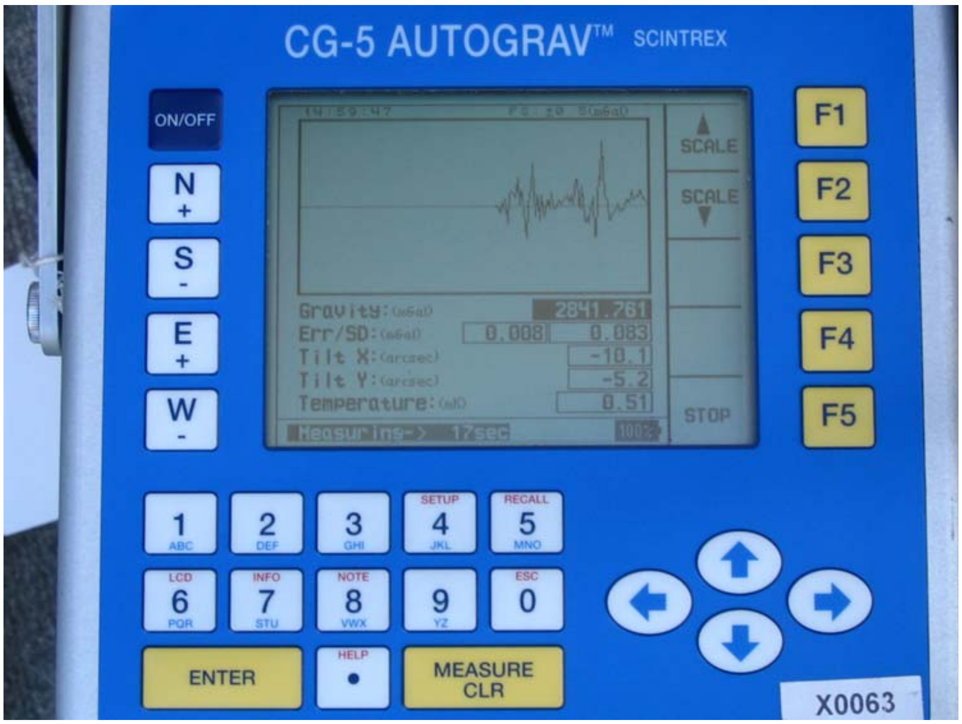
DETERMINATION OF ABSOLUTE GRAVITY AT BPRC/US POLAR ROCK REPOSITORY



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COLUMBUS, OHIO 43210-1002

Determination of Absolute Gravity at BPRC/US Polar Rock Repository

Report of Summer 2005 Gravity Survey

by

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Abstract

We determined absolute gravity at a base station located in the north-east corner of the U.S. Polar Rock Repository based on two field surveys conducted in summer 2005. We used a CG-5 Scintrex Autograv System for our measurements. The meter can measure relative gravity to a precision of 0.001 mGal. To find the absolute gravity we visited three tie-point sites, one located at the OSU Main Library, one in downtown Columbus and one south-west of town near Bolton Airfield. The sites were set up by NOAA and NGS and absolute gravity was determined using a relative gravimeter (Lacoste-Romberg) which in turn was tied back to a site of known gravity. An absolute gravity measurement was conducted by NOAA-NGS in summer 2005 at OSU, in Mendenhall Laboratory. At each of the sites, we recorded a series of gravity measurements. These were subsequently used to calculate absolute gravity at the rock repository base station where measurements were taken at the start and end of the survey. We found the absolute gravity at the base station to be 980082.070 mGal with an error of about 0.035mGal. This report is a summary of this investigation.

Introduction

As part of a study carried out in South-central Greenland, gravity measurements are collected on the ice sheet using a CG-5 Scintrex Autograv System (Jezek and Farness, 2005). This instrument can measure relative gravity with a precision of 0.001 mGal. The determination of gravity at the specific sites provides clues about the mass of the ice that can vary in time and space. In May 2005 we did a local study using this instrument. The goal of this study was:

a) to test and calibrate the instrument before deployment in Greenland, and
b) to determine the absolute gravity at a base station located in the U.S. Polar Rock Repository at the Byrd Polar Research Center (BPRC).

This base station can be used for future field studies and calibration purposes. As the instrument measures only relative gravity it is necessary to use a series of tie points with known absolute gravity to determine the absolute value at the base station. Several of these sites are located in the vicinity of Columbus. We visited these sites and conducted a series of measurements at each of the sites with the instrument.

The CG-5 Scintrex Autograv System

The CG-5 Scintrex Autograv is an automated gravimeter which works based on a quartz spring system. Observations are processed in real time with an onboard microprocessor. Other than an initial leveling, there is no manual intervention in making the measurement hence there is no human induced random error. The measurement range of the instrument is over 8000 mGal and the lowest count is 0.001 mGal. The portability and fast data acquisition scheme of the instrument makes it convenient for large scale surveys.

The instrument measures the relative gravity by sampling at 6 Hz and 6 samples are averaged every second and the reading after each second is displayed. The data is stored in flash memory and subsequently transferred to a computer. The gravity sensor, the control system and the battery are encased in a double casing which increases the stability of the instrument. The leveling of the instrument is done by a software controlled tiltmeter which provides an additional control for slight vertical tilt of the instrument. The sensors of the instrument are kept in a temperature stabilized vacuum chamber for protection against ambient temperature and pressure changes. The gravity spring is made of fused-quartz which is non-magnetic and hence will not be affected by magnetic field variations.

Essentially this instrument uses a simple spring-mass system for the calculation of the gravity at a particular location. A small proof mass is suspended by a spring, made of fused quartz. The spring constant and the mass are known very precisely. The position of the proof mass is sensed by a capacitive displacement transducer. When this small mass is displaced from its initial rest position due to the attraction by another bigger mass, the displacement is sensed by the transducer. This change in the position of the mass results in the generation of a DC voltage by a feedback circuit and the voltage is applied to the capacitive transducer which produces an electrostatic force on the proof mass so that the proof mass is again moved back to the initial position. This applied DC voltage is a measure of the relative gravity and this value is displayed and stored in the memory of the instrument. The gravity sensor and the electronic circuits are designed with such specifications that the feedback voltage covers a range of over 8000 mGal.

The whole measuring unit is encased in a vacuum chamber that provides a stable operating environment and hence the manufacturer specifications claim to predict the corrected long term drift to be less than 0.02 mGal/day. In order to cancel the low frequency noise, a seismic filter is provided. As this instrument has a simple mechanical system and most of the operation is controlled by electronics, there is very little mechanical compensation necessary to correct the final reading.

The reading time of the instrument was set to 30 seconds, the cycle time was 50 seconds and the number of cycles was set to 5. This means the gravimeter starts measuring the gravity for 30 seconds at one particular location, and five 30 second series of observations are recorded. For the present analysis we took the average of the five readings for each of the locations. The basic survey data and the setup options of the gravimeter are given below in the following tables.

CG-5 SETUP PARAMETERS	
Gref:	0
Gcal1:	8407.122
TiltxS:	645.159
TiltyS:	593.252
TiltxO:	-4.962
TiltyO:	9.017
Tempco:	-0.14
Drift:	0.3
DriftTime Start:	13:46:44
DriftDate Start:	5/23/2005

Table 1. The setup parameters for the gravimeter.

CG-5 OPTIONS	
Tide Correction:	YES
Cont. Tilt:	YES
Auto Rejection:	YES
Terrain Corr.:	NO
Seismic Filter:	YES
Raw Data:	NO

Table 2. The various correction options of the gravimeter.

Site Description

The Scintrex CG-5 gives us the relative gravity measurements hence it is necessary to visit some control points where absolute gravity is known either through being a part of the IGSN network or by direct measurement of absolute gravity to verify the accuracy of the data and to set up a relative base station at the polar rock repository. The following is an overview of the sites that we visited for this study in the order that we visited them. The base station was visited first and was reoccupied after the other sites were visited.

Base Station

We set up our base station in the northeast corner of the U.S. Polar Rock Repository next to the Byrd Polar Research Center. This site was chosen because it is least likely to experience any disturbances that occur in the Byrd Center itself due to various activities. The site is marked with a black cross on the ground. It is about 20 cm from the north wall and 20 cm from the east wall/window. Measurements at the base station were done before and after all tie points were visited.

Figure 1. Base station at the U.S. Polar Rock Repository, BPRC.

OSU Library

This site is located just north of the Ohio State University William Oxley Thompson Memorial Library (Main Library on the Oval) on the stairwell leading to the main northern entrance, about 1 m from the wall of the library itself. Close by is a geographic marker indicating 40°N latitude. The actual site is marked with a copper plate placed by NOAA/NGS in 1987. The latitude and longitude of this point are N 39º 59' 58.3'' and W 83º 00' 52.9'' as measured with a simple handheld GPS device. The site might be destroyed in the near future due to library renovations.

Figure 2. Gravimeter at the OSU Main Library.

Old COSI building

This site is located in the basement of the old COSI building in downtown Columbus. The exact address is 280 East Broad Street. Upon arrival at the site the marker was hidden under a thick layer of basement floor paint. We cleaned the marker using a steel brush. The marker was placed by NOAA/NGS in 1987. The site used to be directly underneath a giant pendulum that was used to determine its absolute gravity. The latitude and longitude of this point are N 39 º 57’ 49.78’’ and W 82 º 59’ 35.14’’.

Figure 3. Gravimeter reading at the old COSI basement.

Bolton Airfield

The site is located southwest of Columbus near the Bolton Airfield close to the corner of Norton road and Johnson road. The site is 1 meter above the road and situated on top of a small flood retain wall. It is in the center of three plastic tubes sticking out of the ground. There are a series of geodetic markers running east from there. The latitude and longitude of this point are N 39º 53' 29.7'' and W 83º 09' 16.2''.

Figure 4. Gravimeter being setup for reading at an absolute gravity measurement site near Bolton Airfield.

Results

The recorded data for each of the sites data is given in Appendix 1. The data collected had to be corrected for the drift of the instrument. This is done automatically by the instrument using a tidal model. While processing the data we realized that the tide correction applied to the reading by the instrument was not correct since we had changed the time to EST, while the correction is based on GMT. In order to apply the correct tidal correction, we did some measurements in our lab after setting the instrument time to the corresponding GMT time of our various recordings. The instrument then gives the correct tide corrections on the display. These new set of tide corrections were recorded. We subtracted the incorrect tide correction from the relative gravity values and then added the new set of correct tide corrections. The calculation is shown in Table 3.

Location	Reading	Wrong tide correction	Reading minus wrong tide correction	Correct tide correction	Final reading
BPRC (ba. st.)	2844.196	0.042	2844.154	0.167	2844.321
BPRC (ba. st.)	2844.198	0.042	2844.156	0.167	2844.323
BPRC (ba. st.)	2844.199	0.043	2844.156	0.167	2844.323
BPRC (ba. st.)	2844.197	0.043	2844.154	0.167	2844.321
BPRC (ba. st.)	2844.199	0.044	2844.155	0.167	2844.322
OSU(lib)	2841.848	0.105	2841.743	0.138	2841.881
OSU(lib)	2841.847	0.105	2841.742	0.138	2841.88
OSU(lib)	2841.848	0.105	2841.743	0.138	2841.881
OSU(lib)	2841.851	0.105	2841.746	0.138	2841.884
OSU(lib)	2841.852	0.106	2841.746	0.138	2841.884
Old COSI	2834.596	0.145	2834.451	0.094	2834.545
Old COSI	2834.599	0.145	2834.454	0.094	2834.548
Old COSI	2834.598	0.145	2834.453	0.094	2834.547
Old COSI	2834.601	0.146	2834.455	0.094	2834.549
Old COSI	2834.602	0.146	2834.456	0.094	2834.55
Bolton	2846.885	0.164	2846.721	0.052	2846.773
Bolton	2846.897	0.164	2846.733	0.052	2846.785
Bolton	2846.889	0.164	2846.725	0.052	2846.777
Bolton	2846.888	0.164	2846.724	0.052	2846.776
Bolton	2846.912	0.164	2846.748	0.052	2846.8
BPRC (ba. st.)	2844.438	0.169	2844.269	0.012	2844.281
BPRC (ba. st.)	2844.439	0.169	2844.27	0.012	2844.282
BPRC (ba. st.)	2844.441	0.169	2844.272	0.012	2844.284
BPRC (ba. st.)	2844.443	0.169	2844.274	0.012	2844.286
BPRC (ba. st.)	2844.443	0.169	2844.274	0.012	2844.286

Table 3. The correction for tide.

After rectifying the tide correction, we found out that there was some residual drift in the data, based upon the difference between the initial reading and the final reading at the base station. To correct for this drift we applied a simple linear adjustment to the corrected relative gravity value. The calculation of the drift adjustment was done in the following way.

The time difference between the first and the last reading at the base station (Rock Repository, BPRC) was 3 hr 35 min 54 sec which is approximately equal to 216 min. In this time interval the relative gravity reading 'decreased' by 0.0382 mGal. So in order to correct for this drift 0.0382 was 'added' to last reading. Similarly for all the other three sites, depending on the time that elapsed from the first reading a correction factor was added to the average relative gravity value (Table 4).

Location	Start Time	Time Difference (min)	Correction (mgal)
BPRC (base station)	13:50:48	0	0.000
Library	14:59:42	70	0.0123
Old COSI	15:57:26	128	0.0226
Bolton	16:43:02	174	0.0308
BPRC (base station)	17:26:42	216	0.0382

Table 4. Linear drift correction.

The absolute gravity at the three tie point sites was calculated by NGS in 1987 and the data is available from site:

http://paces.geo.utep.edu/grav_base_stations/OHIO.shtml

Through a personal communication with Dan Winester of NGS, we learned that the measurements at those three sites were made by a relative gravimeter (Lacoste-Romberg) and the absolute gravity values were calculated with respect to an absolute gravity base station at Boston. The accuracy of the absolute gravity values are 0.020 mGal at these three sites, specified on the website.

To test the accuracy of our measurements we calculated the difference between the published absolute gravity values at the sites and compared that with the difference we observed in our data. The difference between these two different sets of data was found out to be within the uncertainty limits. The values are shown in Table 5.

Locations	Absolute difference (mGal)	Measured difference (mGal)
OSU_Lib – Old_Cosi	7.388	7.334
Bolton – Old Cosi	12.287	12.234
OSU_Lib – Bolton	4.899	4.900

Table 5. Comparison of the absolute and relative gravity differences between the sites.

In order to calculate the absolute gravity at our base station (BPRC rock repository) we performed a linear regression analysis. We plotted the absolute and the relative gravity values after subtracting the mean and dividing by the standard deviation from each data set, so that the regression is sensitive to the dataset. We fitted a straight line to the data and obtained an empirical relationship between the scaled absolute (G') and relative (g') gravity. The relationship between the absolute (G) and the relative (g) gravity was found out to be

$$G = g + 977237.745 \qquad \text{---------------------} \ (1)$$

We substituted the relative gravity measured at the rock repository and found out the absolute value. The calculation is shown in Table 6 and the plot is shown in Figure 5. Based on these calculations we found the absolute gravity at the base station to be 980082.077 mGal with an approximate error of 0.035 mGal. The error was calculated by averaging the residuals between the difference in the absolute and the relative gravity measurements.

Locations	**Absolute gravity (G)**	$G' = (G - \overline{G}) / \sigma_G$	**Measured Anomalies(g)**	$g' = (g - \overline{g}) / \sigma_g$
OSU	980079.654	0.134133739	2841.894	0.151678619
Cosi	980072.266	-1.060297839	2834.5704	-1.234207021
Bolton	980084.553	0.9261641	2846.813	1.082528402

Table 6. Calculation of absolute gravity at the Rock Repository, BPRC.

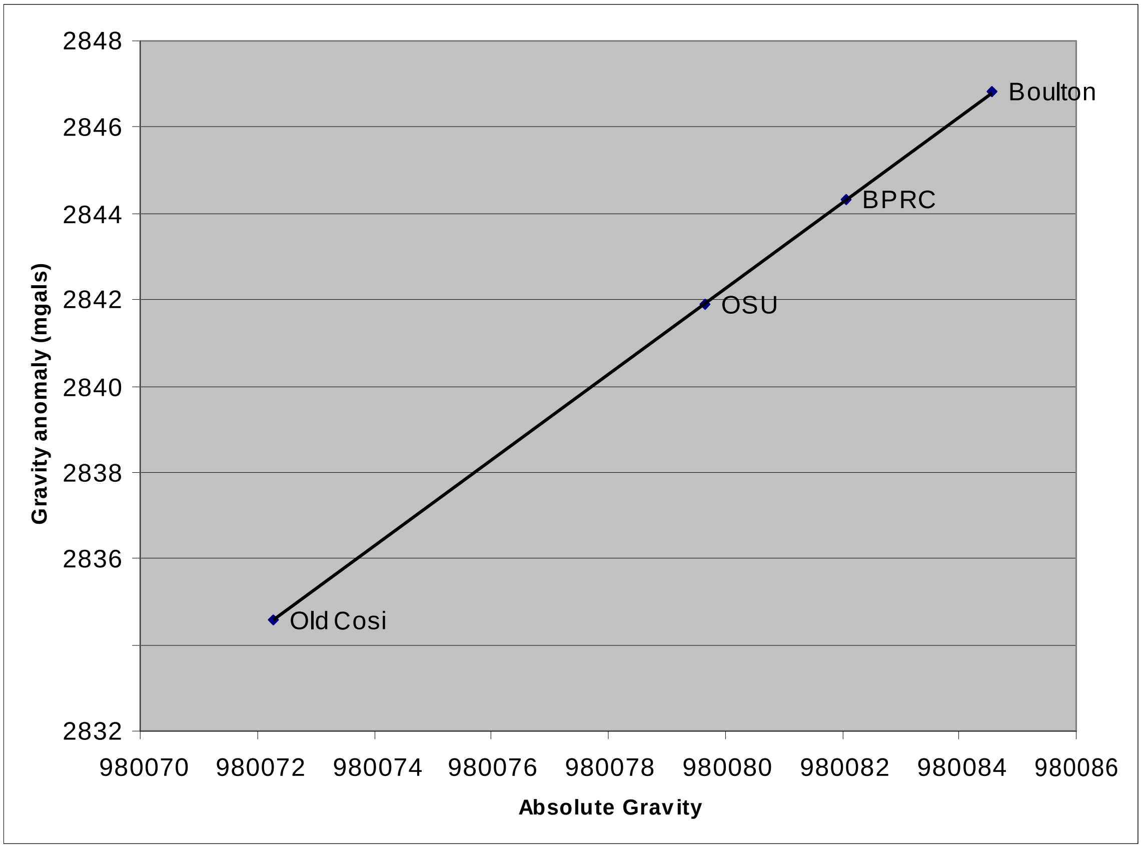

Figure 5. Regression fit to the absolute and relative gravity data.

Comparison and Discussion

During summer of 2005 an absolute gravity field measurement was conducted by Dan Winester, National Geodetic Survey, NOAA. As a part of this survey, an absolute gravity measurement point was demarcated at the basement of Mendenhall, School of Earth Sciences (previously Department of Geological Sciences), at OSU. The results of the absolute gravity measurements around Columbus, including the one at Mendenhall are provided in the Appendix. The absolute value can be used indirectly to check the absolute gravity value derived for BPRC using the relative gravimeter. We conducted another field survey on 13th July, 2005 which included the same gravity measurement point at BPRC as of the earlier survey and the absolute gravity measurement point at Mendenhall. The recorded data is given in Appendix 1. Unlike the previous survey, we didn't change the time and hence our tide correction was correct and the only correction necessary was the drift correction. During our survey of approximately 85 minutes, the relative gravimeter reading decreased by 0.055 mGal and hence using a linear drift correction we added 0.055 mGal to the last reading and the reading at the other locations depending on the time difference. The corrections are shown in the Table 7 below.

Location	Start Time	Time Difference (min.)	Correction (mGal)
BPRC (base station)	18:33:23	0	0.000
Library	19:05:07	32	0.0207
Mendenhall	19:25:40	52	0.0336
BPRC (base station)	19:58:46	85	0.055

Table 7. Linear drift correction.

After applying the drift correction the relative gravity anomaly at library, Mendenhall and BPRC was calculated to be 2844.965, 2845.576 and 2847.388 mGal respectively. We argue that the difference in the relative gravity (say Δ_R) at two locations and the difference in the absolute gravity (say Δ_{ABS}) will be the same. To validate our argument we choose two locations where both the relative and absolute gravity measurements are available i.e. Main Library (OSU) and Mendenhall. The relative gravity difference between Mendenhall and Library is 0.0611 mGal. From the absolute gravity value data obtained from Dan Winester, we find out that the difference in the absolute gravity between Mendenhall and the OSU Main library is 0.061 mGal. This result gives confidence to our argument and we can use this logic to verify and compare the absolute gravity value calculated earlier at the Polar Rock Repository, BPRC.

As the difference between the relative gravity anomaly at BPRC and Mendenhall is 1.1812 mGal we expect the difference in the absolute gravity between these two sites will also be 1.1812 mGal. The absolute gravity estimate of Mendenhall measured by Dan Winester is 980080.251 mGal. Hence adding the relative gravity difference (which is 1.1812 mGals) to this absolute value will give us the absolute gravity at BPRC. Following this logic, the absolute gravity value calculated for BPRC is 9800082.063 mGal and the difference from our previous estimate is 0.014 mGal which is well within the accuracy of the relative gravimeter. This result gives us confidence in our derived absolute gravity value for BPRC site.

The relative gravity anomaly measured at OSU library and BPRC rock repository during the second survey was higher than the first survey. The difference for the library was 3.071 mGal and for BPRC it was 3.056 mGal. Since we measure the relative gravity variation at theses locations and the measurements were done after a gap of approximately one and half months, we expect the reading not to be exactly the same. But the difference for both BPRC and library is almost the same and their difference (3.071-3.056 =0.015 mGals) is within the accuracy of the gravimeter. We considered the average of theses two differences ((3.071+3.056)/2 = 3.0635 mGals) and subtracted this averaged swing from the second survey measurement value at BPRC (2847.388-3.064 = 2844.324 mGal). We use equation 1 to calculate the absolute gravity corresponding to this relative anomaly and estimate at BPRC is 980082.069 mGal. If we compare our first estimate (980082.077 mGal) based on the first survey, the difference of the two estimates (0.008 mGal) is well within the accuracy of the relative gravimeter.

To conclude, we estimate the absolute gravity value at BPRC Polar Rock Repository, BPRC based on two field surveys and from the absolute measurements made by Dan Winester at Mendenhall. We came up with three values which were close enough to each other given the accuracy of the relative gravimeter (0.04 mGal). The first estimate based on first field survey is 980082.077 mGal, based on second field estimate

980082.069 mGal and in comparison with Dan Winester absolute measurement at Mendenhall 980082.063 mGal. The difference between all theses three estimates fall within the accuracy of the Scientrix Autograv relative gravimeter. The average of theses three values is 980082.070 mGal which is our best estimate for the absolute gravity at Polar Rock Repository, BPRC.

Summary

We successfully tested and calibrated the Scintrex gravity meter. We visited four established absolute gravity sites in and around Columbus and did measurements at each of the sites. Using these locations as tie points we established another gravity site in the U.S. Polar Rock Repository at the Byrd Polar Research Center by doing a linear regression analysis of the recorded data and using the absolute gravity data measured at OSU Mendenhall Lab. The newly established site is suitable for future field studies as calibration site. We found the gravity at the new site to be 980082.070 mGal with an estimated error of approximately 0.035mGal.

References

CG-5 Scintrex Autograv System Operation Manual, Release 0, Apr. 2003.

Longman, I.M. 1959. Formulas for computing the tidal accelerations due to the moon and the sun. *Journal of Geophysical Research*, **64**(12), 2351-2355.

Jezek, K.C. and K.L. Farness. 2005. *Coupled Gravity and Elevation Measurements, Report of the June 2005 Field Season.* Byrd Polar Research Center Technical Report.

Appendix 1 – Recorded Data

Table 8. The recorded data at the base station at the U.S. Polar Rock Repository, BPRC.

GRAV	SD	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2844.196	0.033	1.1	0.5	0.3	0.042	30	0	13:50:48	5/23/2005
2844.198	0.021	0.8	0.8	0.3	0.042	30	0	13:51:24	5/23/2005
2844.199	0.022	0.5	1	0.3	0.043	30	0	13:51:56	5/23/2005
2844.197	0.01	0.3	1	0.29	0.043	30	0	13:52:28	5/23/2005
2844.199	0.023	0	1.2	0.29	0.044	30	0	13:53:01	5/23/2005

Table 9. The recorded data at the university Main Library.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2841.848	0.048	-10.4	-5.2	0.51	0.105	30	6	14:59:42	5/23/2005
2841.847	0.019	-10.3	-5.5	0.5	0.105	30	0	15:00:18	5/23/2005
2841.848	0.015	-10.1	-6.1	0.48	0.105	30	0	15:00:50	5/23/2005
2841.851	0.039	-10.5	-5.8	0.47	0.105	30	0	15:01:22	5/23/2005
2841.852	0.027	-10.7	-6	0.46	0.106	30	0	15:01:55	5/23/2005

Table 10. The recorded data at the Old Cosi building, downtown, Columbus.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2834.596	0.023	10.8	-1.3	0.52	0.145	30	0	15:57:26	5/23/2005
2834.599	0.022	12.3	-1.2	0.51	0.145	30	0	15:58:02	5/23/2005
2834.598	0.02	13	-1.4	0.5	0.145	30	0	15:58:34	5/23/2005
2834.601	0.015	13.6	-1.5	0.49	0.146	30	0	15:59:06	5/23/2005
2834.602	0.023	13.9	-1.7	0.48	0.146	30	0	15:59:39	5/23/2005

Table 11. The recorded data at Bolton Air Field.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2846.885	0.026	2.9	3.9	0.65	0.164	30	0	16:43:02	5/23/2005
2846.897	0.035	4.5	2.7	0.64	0.164	30	1	16:43:38	5/23/2005
2846.889	0.04	4.4	3	0.63	0.164	30	2	16:44:10	5/23/2005
2846.888	0.033	4.4	1.4	0.63	0.164	30	0	16:44:42	5/23/2005
2846.912	0.044	5	1.4	0.62	0.164	30	4	16:45:15	5/23/2005

Table 12. The recorded data at base station at the U.S. Polar Rock Repository, BPRC.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2844.438	0.016	-3.8	2.8	0.58	0.169	30	0	17:26:42	5/23/2005
2844.439	0.029	-4.2	3.4	0.58	0.169	30	0	17:27:18	5/23/2005
2844.441	0.018	-3.5	2.1	0.57	0.169	30	0	17:27:50	5/23/2005
2844.443	0.017	-3.1	1.7	0.57	0.169	30	0	17:28:22	5/23/2005
2844.443	0.022	-2.8	1.4	0.56	0.169	30	0	17:28:55	5/23/2005

Table 13. The absolute gravity measurement data, courtesy of Dan Winester, NOAA-National Geodetic Survey.

	LATITUDE (N)			LONGITUDE(W)			ELEV	SURVEY	FINAL g	FINAL
DESIGNATION	DD	MM	SS.SSS	DDD	MM	SS.SSS	(m)	DATE	(uGal)	ERROR
BOLTON CAL BL 0	39	53	29.614	83	9	15.220	272.57	09/30/1987	980,084,540.0	9.1
COLUMBUS	39	57	49.784	82	59	35.136	231.3	10/01/1987	980,072,252.5	9.3
COLUMBUS AA	39	59	53.1	83	0	39.2	226.10	07/02/2005	980,080,250.5	2.2
COLUMBUS AA (091 CM)	39	59	53.1	83	0	39.2	227.01	07/02/2005	980,079,978.2	2.6
COLUMBUS AA (131 CM)	39	59	53.1	83	0	39.2	227.41	07/02/2005	980,079,855.5	1.9
COLUMBUS B-1	39	59	57.8	83	0	53.3	231.9	07/01/2005	980,079,640.9	4.4
COLUMBUS C	39	59	25.0	83	2	34.2	245.6	09/30/1987	980,081,374.8	9.0
COLUMBUS J	39	59	54	82	52	12	244.8	12/01/1986	980,064,202.0	16.6
COLUMBUS LATITUDE	40	0	0.218	83	0	53.65	231.167	07/02/2005	980,080,057.1	4.0
COLUMBUS V 189	39	59	53	82	52	12	248.210	12/01/1986	980,064,270.0	12.0
DAYTON AA	39	44	2.8	84	9	47.26	270.3	06/24/2005	980,065,467.7	3.1
DAYTON AA (091 CM)	39	44	2.8	84	9	47.26	271.21	06/24/2005	980,065,246.3	3.5
DAYTON AA (131 CM)	39	44	2.8	84	9	47.26	271.61	06/24/2005	980,065,150.5	1.9
DAYTON CA	39	44	3.130	84	9	47.262	272.595	06/24/2005	980,065,333.3	3.6
EATON AA	39	44	37.0	84	38	8.1	316.22	06/28/2005	980,033,011.2	2.6
EATON AA (091 CM)	39	44	37.0	84	38	8.1	317.13	06/28/2005	980,032,756.8	4.6
EATON AA (131 CM)	39	44	37.0	84	38	8.1	317.53	06/28/2005	980,032,644.6	1.9
EATON CA	39	44	35.984	84	38	8.045	318.104	06/28/2005	980,032,634.7	3.7
LEBANON AA	39	25	53	84	17	3	256.2	06/29/2005	980,020,584.3	2.2
LEBANON AA (091 CM)	39	25	53	84	17	3	257.11	06/29/2005	980,020,308.8	2.6
LEBANON AA (131 CM)	39	25	53	84	17	3	257.51	06/29/2005	980,020,182.3	1.9
LEBANON DIS GAR (5 CM)	39	25	49.489	84	17	0.279	256.265	06/27/2005	980,020,363.7	4.6
PERRYSBURG TT 16 WO	41	33	26.39	83	37	40.03	192.397	12/01/1986	980,228,359.0	12.0

Table 14. The recorded data at the base station at the U.S. Polar Rock Repository, BPRC, second survey.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2847.389	0.009	6.3	2.7	0.09	0	30	0	18:33:23	7/13/2005
2847.387	0.007	6.6	2.5	0.09	0	30	0	18:34:00	7/13/2005
2847.388	0.008	6.5	2.4	0.08	0	30	1	18:34:32	7/13/2005
2847.388	0.009	6.4	2.3	0.08	0	30	0	18:35:04	7/13/2005
2847.389	0.008	6.3	2.2	0.07	0	30	0	18:35:37	7/13/2005

Table 15. The recorded data at the Main Library, OSU, second survey.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2844.942	0.014	-3.2	5.7	0.37	0.004	30	3	19:05:07	7/13/2005
2844.944	0.017	-3.7	5.8	0.37	0.004	30	2	19:05:44	7/13/2005
2844.944	0.011	-4.4	6.1	0.37	0.004	30	1	19:06:16	7/13/2005
2844.944	0.022	-4.7	6.3	0.36	0.004	30	21	19:06:48	7/13/2005
2844.946	0.016	-4.8	6.2	0.36	0.004	30	1	19:07:21	7/13/2005

Table 16. The recorded data at Mendenhall Laboratory, School of Earth Sciences, OSU.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2845.538	0.008	-6.3	-4.9	0.36	0.008	30	0	19:25:40	7/13/2005
2845.542	0.008	-6.8	-4.5	0.37	0.008	30	7	19:26:17	7/13/2005
2845.542	0.011	-7	-4.3	0.36	0.008	30	6	19:26:49	7/13/2005
2845.545	0.011	-6.9	-4.3	0.36	0.008	30	1	19:27:21	7/13/2005
2845.544	0.007	-6.9	-4.1	0.36	0.008	30	0	19:27:54	7/13/2005

Table 17. The recorded data at base station, U.S. Polar Rock Repository, BPRC.

GRAV.	SD.	TILTX	TILTY	TEMP	TIDE	DUR	REJ	TIME	DATE
2847.325	0.01	0.6	3.9	0.44	0.013	30	10	19:56:32	7/13/2005
2847.329	0.01	1.4	4.2	0.45	0.013	30	1	19:57:09	7/13/2005
2847.335	0.013	2.2	4.3	0.45	0.013	30	0	19:57:41	7/13/2005
2847.338	0.017	2.8	4.4	0.45	0.013	30	2	19:58:13	7/13/2005
2847.339	0.007	3.3	4.4	0.45	0.013	30	0	19:58:46	7/13/2005